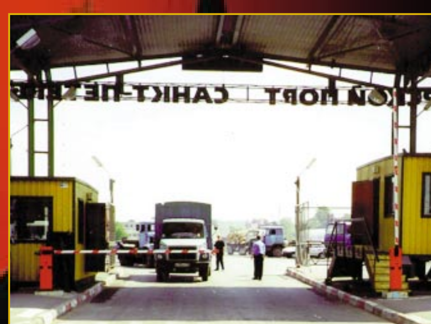
Preventing Nuclear Proliferation

Livermore experts spend long weeks away from home helping to secure nuclear materials and weapons know-how in the former Soviet Union.



TO some observers, the end of the Cold War and sudden collapse of the Soviet Union posed a more dangerous situation than the Cold War itself. The problem was economic and political instability in a region laden with a large number of nuclear weapons, nuclear materials, and nuclear weapons scientists. With the collapse of centrally maintained controls, managing nuclear weapons, materials, and expertise to prevent their transfer to other nations or even terrorists became an urgent task for Russia and the other newly independent states—and an opportunity for the United States to provide assistance.

As Lawrence Livermore Director Bruce Tarter notes, "It is in the interest of the world and the U.S. to work with Russians to contain nuclear weapons, nuclear materials, and nuclear experts within the framework of a stable society." The U.S. Department of Energy and its national laboratories have been given responsibility for developing programs with Russia's Ministry of Atomic Energy (Minatom) and other agencies in the former Soviet Union.

Livermore's Russian programs are concentrated in the Nonproliferation, Arms Control, and International Security (NAI) Directorate, specifically its Proliferation Prevention and Arms Control program. According to physicist William Dunlop, the program leader, Livermore's Russian programs draw upon a wide range of Laboratory strengths, including nuclear materials characterization, radiation detection, forensic science, computer simulation, site security, weapons physics research, and design, testing, and dismantlement.

At nuclear materials storage facilities, weapons laboratories, remote customs sites, and airports and seaports across Russia and the other newly independent states, Livermore men and

The Post–Cold War Challenge

women spend long weeks away from home helping to make nuclear materials and weapons know-how more secure. Despite occasional setbacks—and sometimes difficult negotiations—their progress is a testament to the strong professional relationships they have established with their colleagues in the former Soviet Union.

One telling mark of progress appeared in March when Lawrence Livermore signed the first contract between a DOE laboratory and a Russian nuclear weapons manufacturing plant. The partnership with the Avangard Foundation, an independent Russian business that is the commercial-projects-gathering arm of the Avangard production plant, contracts for the manufacture of kidney dialysis equipment in the closed city of Sarov. Until the 1990s, Western researchers were not allowed to visit the highly secure city; it and other cities like it dedicated to nuclear weapons activities were not even on maps.

Livermore's Russian programs currently take one of two thrusts. The first is enhancing the protection, control, and accounting of weapons-usable nuclear materials and technologies. The second is helping to find new nonweapons job opportunities for the former Soviet weapons scientists. Taken together, these programs address two of the key proliferation concerns in Russia.

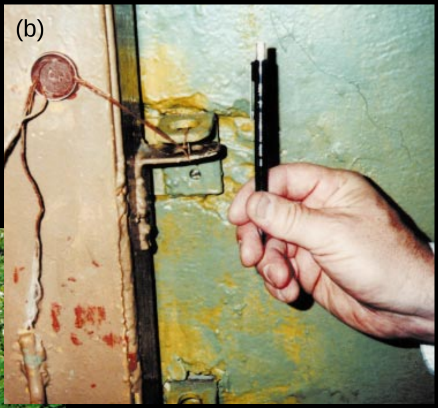
Countering Nuclear Theft

In 1993, the U.S. in partnership with the newly independent states formed a first line of defense against the theft of nuclear materials. The threat is particularly acute in Russia because the Russians have a large number of nuclear storage facilities and nuclear materials producers and exporters but lack an overall system to track or control these materials.

The Material Protection, Control, and Accounting program works with Minatom civil and weapons complexes, the independent Russian civil sector, the Russian nuclear navy, uranium and plutonium storage sites, and reactor and fuel facilities. The program protects against both insider and outsider theft with a host of physical security measures and systems to protect and monitor nuclear materials. Enhancements range from the installation of new fences and modern locks to sensitive radiation detection equipment and sophisticated alarm systems.

In analyzing a site, Livermore experts look for vulnerabilities such as inadequate access control systems and poorly protected building perimeters. For example, doors to vaults holding nuclear materials may have been secured using only wax-and-string seals to detect unauthorized entry. There may be no metal or radiation detectors at entrances to and exits from sensitive areas. Also, areas around facilities may be overgrown and poorly protected by fences and sensors.

Livermore project leader Scott McAllister notes that most U.S. principles, techniques, and tools for nuclear material protection, control, and accounting have been developed by or in conjunction with DOE national laboratories. Livermore personnel apply this longstanding expertise when working with their Russian colleagues. A Livermore employee visiting one of the upgraded sites in Russia would notice many similarities to the equipment and procedures currently used throughout the DOE complex. Examples include access control booths at building entrances, identification badges read by computerized systems to control access to high-security areas, and metal and nuclear material detectors to check people entering and leaving



(a) Before material protection, control, and accounting efforts began, areas around Russian nuclear facilities were, in some cases, overgrown and poorly protected by fences and sensors. (b) Inside, doors to vaults holding nuclear material may have been secured with only wax-and-string seals to detect unauthorized entry.

facilities containing nuclear material. "We're helping the Russians update their old system of 'guards, guns, and gates' with more sophisticated technical systems," McAllister says.

Livermore-aided upgrades are currently in place at many of the more than 300 buildings located at over 50 sites included in the program. These sites include some of the most important nuclear institutes in Russia, such as the All-Russian Scientific Research Institute of Technical Physics in Snezhinsk (formerly known as Chelyabinsk-70), a facility similar to Los Alamos or Livermore.

Livermore people also work with the Northern and Pacific fleets of the Russian Navy to strengthen the protection of highly enriched reactor fuel for nuclear-powered vessels. This work involves direct interactions with the Russian Ministry of Defense to characterize the sites, define the necessary improvements, and help implement upgrades, a situation that would have been inconceivable only 10 years ago. Livermore also manages development and implementation of the Federal Information System project, a comprehensive system for tracking Russia's nuclear material inventory.

A Second Line of Defense

The Russian Federation State Customs Committee must deal with 20,000 kilometers of border to 14 nations, including Iran and North Korea. However, authorities have insufficient funds for equipping customs sites with modern technology to detect illicit nuclear materials trafficking. Since 1997, DOE's Second Line of Defense program has been providing an additional layer of assurance by helping to protect the most important customs control sites and border points in Russia. Says Livermore project manager Jeff Richardson, "We're establishing one more layer of defense that did not exist until very recently."

The program supports the development and installation of Russian-manufactured nuclear detection equipment and provides better training for front-line customs officers. Livermore's capabilities in radiation detection and forensic science are central to these efforts; a team of Russian customs officials and other government representatives visited Livermore in November 1998 and December 1999 for a series of workshops on preventing the smuggling of nuclear materials.

The program has already achieved several key milestones. In 1998, a U.S.–Russian team led by Los Alamos National Laboratory equipped Moscow's Sheremetyvo International Airport with radiation detection equipment, including pedestrian portal monitors for departing passengers. The ceremony commissioning the equipment was part of the U.S.–Russia presidential summit in September 1998. Future airport upgrades will include a cargo monitoring system, a system for improved detection of shielded nuclear materials, and technical training for customs officers.

Also completed in 1998 was the Livermore effort to install pedestrian and vehicle monitoring portals at Astrakhan, a major seaport on the Caspian Sea for shipments to Iran and

(a) Livermore scientists and engineers helped to design a hardened annex to an existing Russian nuclear material storage bunker. (b) Upgraded facilities often include such modern systems as access control booths.

beyond. The following year, systems for monitoring rail cars were installed, and the development of new training programs began.

The Second Line of Defense has surveyed customs inspection posts at Vladivostok, Vostochniy, Olya, Rostov, and Novorossiysk—all cities situated along Russia's southern and eastern borders—for future equipment upgrades. In 1999, Livermore completed a study prioritizing the remaining customs points and border posts, including those on the Black Sea and the Caspian Sea and those bordering North Korea and Kazakhstan.

In addition, Livermore experts in cooperation with Russian Customs Academy colleagues are developing a training program for customs officers. Under this program, Russian technical experts will instruct students and inspectors on how to use radiation portal monitors and handheld detectors, how to spot anomalies in export documents and manifests, and how to examine containers that might hide nuclear material.

Richardson says a particular technical challenge is detecting and identifying weak nuclear radiation sources such as highly enriched uranium. This year saw the initial development of Russian equipment employing what is known as active neutron interrogation. The equipment will bombard suspected cargoes with neutrons to detect illicit highly enriched uranium shipments.

Warheads Pose Challenges

Ironically, the success of nuclear arms reduction agreements has compounded the problem of monitoring nuclear materials. Both Russia and the U.S. are dismantling thousands of nuclear warheads. In April 2000, Russia's Duma ratified the Strategic Arms Reduction Treaty (START) II that cuts each side's strategic nuclear arsenal to between 3,000 and 3,500 warheads, down from the 6,000 level under START I. (The U.S. Senate ratified START II in 1996.) Future treaties could present several challenges to the West, such as verifying that warheads are in fact being dismantled, that the dismantlement is irreversible, and that the nuclear materials separated from the weapons are accounted for and secure.

Many of Livermore's warhead dismantlement activities support the 1997 Helsinki summit accords. Presidents Clinton and Yeltsin declared then that each country would remove 50 metric tons of plutonium from its nuclear weapons program and ensure that the material could never again be used in weapons. The June 2000 U.S.–Russian Moscow summit builds upon the Helsinki agreements by specifying the plans, schedules, and methods for making 34 metric tons of plutonium inaccessible for use in nuclear weapons.

The International Atomic Energy Association (IAEA) is expected to have responsibilities for monitoring this plutonium. Livermore experts are helping to establish the U.S.–Russian–IAEA inspection system for the plutonium that is scheduled to be stored at the Mayak facility in the Ural Mountains. The U.S. is providing $400 million in goods and services toward construction of this storage facility, which is scheduled for completion in 2003. The U.S. has proposed using advanced detection systems that will verify, without revealing classified information, that the plutonium arriving at Mayak came from dismantled nuclear weapons. Jim Morgan, leader of Livermore's Radiation Technology Group, says that the detection system

(a) Cars and (b) trains leaving and entering Astrakhan on the Caspian Sea are monitored for nuclear materials.

will be demonstrated to Russian experts at Los Alamos National Laboratory this fall. The meeting will be a follow-up to a joint workshop that was held at Livermore in 1997 to demonstrate high-resolution gamma-ray spectrometry for analyzing weapons-grade plutonium.

Livermore scientists also participate in DOE's Lab-to-Lab Warhead Dismantlement Transparency program. This effort encourages Russian and American dismantlement experts to discuss ways to improve transparency through measures increasing confidence that agreed-to actions are taking place. Livermore is responsible for developing transparency measures for the conversion in Russia of 500 metric tons of highly enriched uranium from dismantled nuclear warheads to low-enrichment uranium. The U.S. is purchasing the converted uranium to fuel its civil nuclear power reactors. The highly enriched uranium effort is currently managed by Livermore's Energy Programs Directorate in close cooperation with the NAI Directorate.

Laboratory experts are also involved in negotiations with Russia to convert its three remaining weapons-grade plutonium production reactors to civil use (the U.S. has ceased producing weapons-grade plutonium). In return, the U.S. is allowed to monitor the 14 metric tons of weapons-grade plutonium oxide produced at the reactors from January 1, 1997, until the reactors are converted.

Disposing of Plutonium

Russia has long considered weapons-grade plutonium recovered from its intermediate products and wastes to be too important a national resource for permanent immobilization, which would ensure that it could never again be used for weapons. Their standard practice is to reprocess all plutonium-containing wastes and recycle the plutonium for their weapons program or as mixed oxide (MOX) fuel for reactors.

In contrast, the U.S. has decided on a dual-track approach. Relatively clean plutonium will be used for MOX reactor fuel, while impure plutonium will be immobilized. In the immobilization approach, plutonium is one constituent of a ceramic waste form, with a neutron-absorbing material added to the ceramic to prevent a nuclear chain reaction during long-term storage in a geologic repository. The plutonium-containing ceramic is sealed inside cans, the cans are placed in a stainless-steel canister, and the canister is filled with molten glass containing high-level defense wastes to further increase the plutonium's inaccessibility.

Livermore experts are helping to upgrade the training of Russian customs officers to detect illicit trafficking in nuclear materials or related equipment.

Livermore scientists are leading the DOE program to develop U.S. immobilization technology. They have also been encouraging their Russian colleagues to consider immobilizing some of their plutonium. Russian scientists are familiar with the concept. Since 1995, Russian scientists have toured Livermore's plutonium facility on six occasions (most recently in July 2000) to learn more about immobilization techniques.

Led by engineer Les Jardine, a Laboratory team has successfully encouraged Minatom officials to proceed with research and development, engineering, and system analysis for immobilizing a portion of its plutonium inventory. This plutonium would come from materials, residues, and wastes with concentrations higher than 200 parts per million. "We showed the Russians that it makes more economic sense to immobilize rather than reprocess some of their plutonium," says Livermore's Lee MacLean.

The current objective is to develop a Russian capability for industrial-scale immobilization of plutonium by 2005. Over 30 contracts have been placed with Russian institutes. The contracts include engineering feasibility studies at the Krasnoyarsk and Mayak industrial sites and research efforts at Russian scientific institutes to develop glass and ceramic immobilization forms. Russian and U.S. scientists have also defined the nonproliferation safeguards needed to prevent terrorists from retrieving the plutonium from its immobilized form.

In May, Lawrence Livermore received a plutonium oxide saltwasher it had purchased from the Russian Scientific Research Institute of Atomic Reactors. Once adapted to U.S. electrical standards, the machine will be tested at Livermore's plutonium facility, where it is expected to provide a more efficient method for preparing U.S. plutonium for immobilization.

According to Jardine, the equipment "shows that their technical people are extremely competent and are capable of efficiently handling plutonium fissile materials."

Test Ban Treaty Collaborations

Livermore scientists are involved in a host of interactions with Russia in the context of the Comprehensive Test Ban Treaty (CTBT). Livermore teams support the U.S.–Russian CTBT Monitoring and Verification Working Group and collaborate on research projects related to the treaty, including on-site inspection measures.

Although not yet ratified by all participants, the treaty, which forbids all nuclear detonations, creates an international monitoring network to search for evidence of clandestine nuclear explosions. Livermore and Russian scientists are documenting how regional geology would affect the transmission of seismic signals from low-yield underground nuclear tests. They are also working to differentiate the seismic signals of a clandestine underground nuclear test from those of a mining blast or earthquake.

An allied effort is the On-Site Inspection program, which supports the CTBT Preparatory Commission in Vienna by defining the technologies, procedures, and equipment that would guide on-site inspections. Under terms of the treaty, a nation suspecting another of conducting a nuclear test may request an on-site inspection to determine the nature of an ambiguous event. The inspections must be conducted quickly in order to collect information about short-lived phenomena, such as seismic aftershocks, that are produced by an underground nuclear explosion.

A major milestone occurred in October 1998 when a joint on-site inspection exercise was conducted at Snezhinsk, Russia. The exercise played out the first 15 days of a hypothetical on-site inspection. In the exercise, separate U.S. and Russian inspection teams analyzed simulated data from visual, seismic, and radionuclide sources.

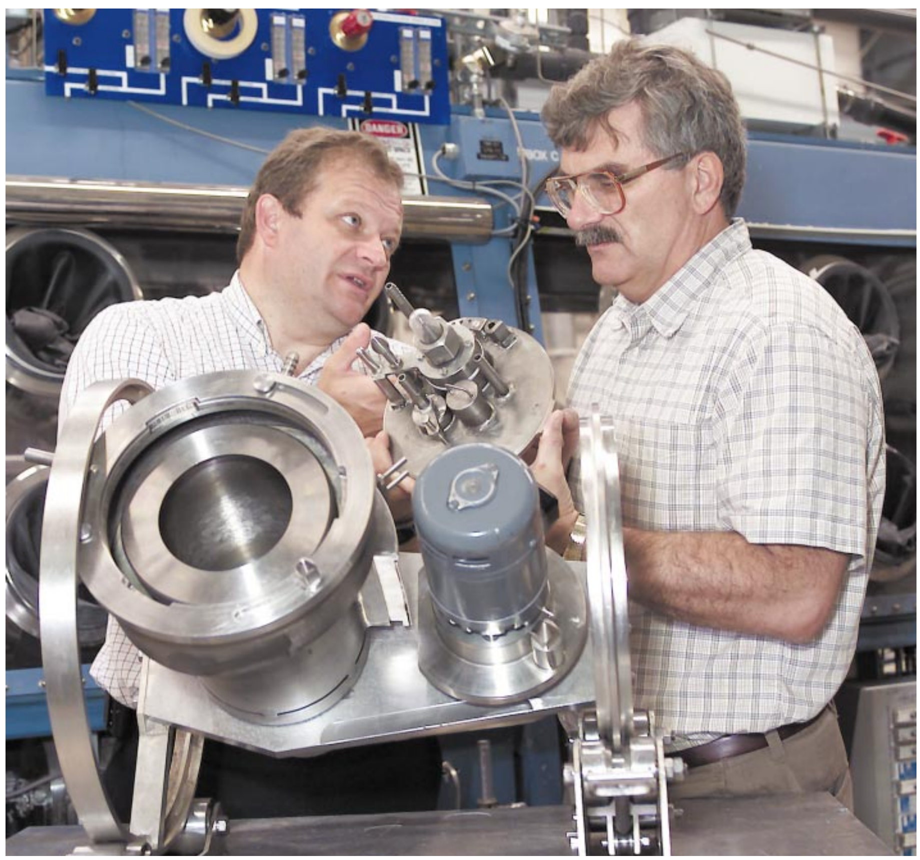
A second exercise was successfully completed in April 2000, again in Snezhinsk. Livermore geologist Jerry Sweeney says that this exercise was even more cooperative than the first because inspection teams were composed of both Russians and Americans. "The exercise was valuable because we saw how an international inspection team might function," he says.

Livermore is also collaborating on several CTBT-related research projects sponsored by the International Science and Technology Center. One project is investigating electromagnetic signals accompanying underground chemical explosions as a way to enhance the discrimination between chemical and nuclear explosions.

Another project is using powerful mechanical seismic vibrators to produce 1- to 8-hertz waves that can be detected at distances of up to 500 kilometers. The goal is to determine if the semiportable vibrators (essentially a railroad tank car placed on end, combined with an air bladder to shift water at a given frequency) can cost-effectively substitute for large explosion sources that are commonly used to calibrate regional CTBT monitoring stations.

Keeping Expertise at Home

Two DOE programs, the Initiatives for Proliferation Prevention and the

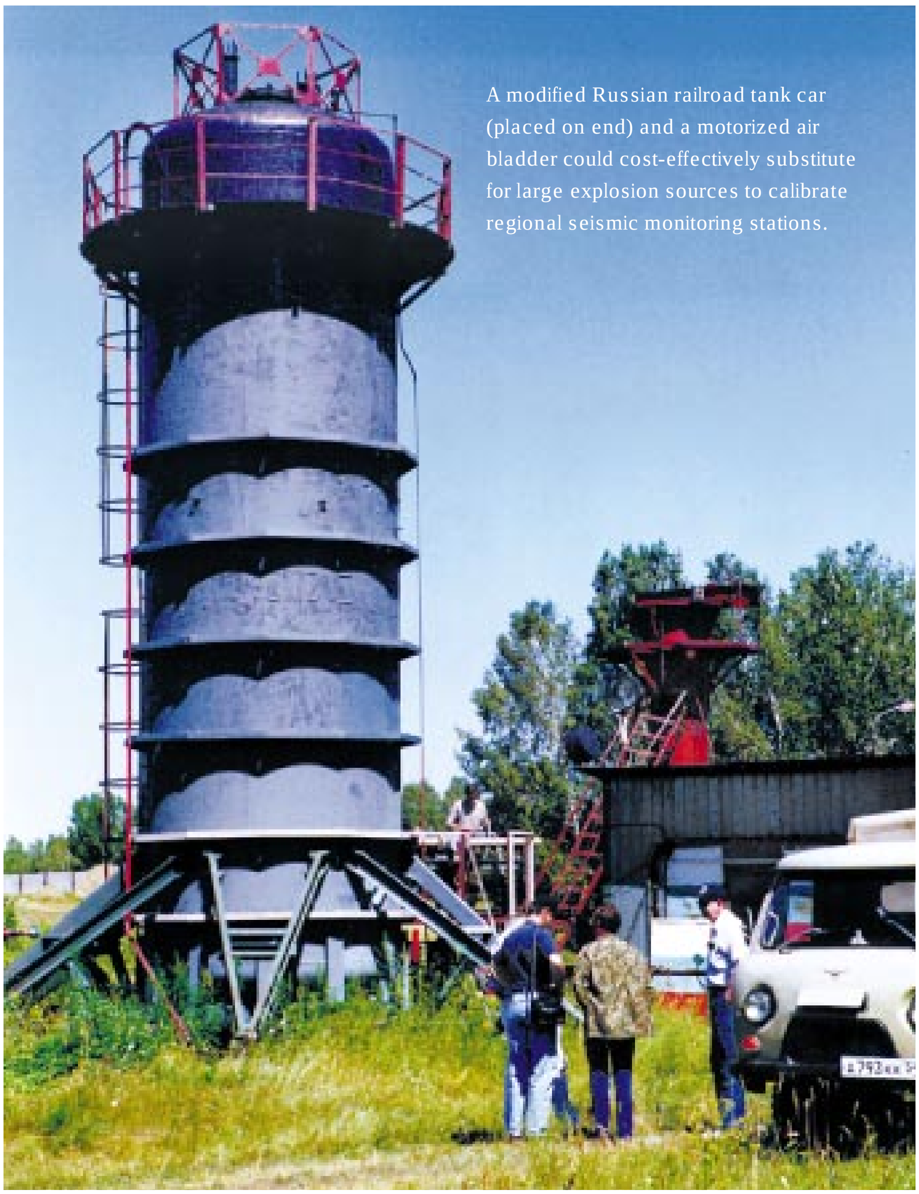


Livermore's Mark Bronson (left) and Les Jardine examine the Russian-designed and built plutonium oxide saltwasher that is being tested for use in the U.S. plutonium disposition program.

Nuclear Cities Initiative, focus on preventing the movement of technical knowledge and expertise from the former Soviet nuclear weapon complex to other nations or terrorist organizations. Both programs attempt to develop self-sustaining nonweapons-related work for former nuclear scientists, engineers, and technicians and introduce the basic principles of market economics and Western business practices.

Founded in 1994, the Initiatives for Proliferation Prevention (IPP) promotes collaborative projects among DOE's national laboratories, U.S. industry partners, and 170 institutes in the newly independent states. The goal is to attract investment by U.S. companies that will lead to self-sustaining business ventures and provide long-term employment opportunities for former Soviet weapons workers.

The approach involves three steps. First, Livermore works with weapons scientists and institutes to identify and evaluate the commercial potential of research and development activities at the institutes. Second, partnerships are formed with U.S. industry, and DOE shares the investment costs. During the final phase, U.S. industry and the institutes continue the commercial relationship without DOE participation.



A modified Russian railroad tank car (placed on end) and a motorized air bladder could cost-effectively substitute for large explosion sources to calibrate regional seismic monitoring stations.

Project leader Ted Saito says that Lawrence Livermore's longstanding knowledge of those institutes, its people, and their capabilities makes the Laboratory an excellent facilitator for U.S. companies. Livermore scientists and engineers bridge communication gaps and contribute to the evaluation of technical and economic potential by U.S. companies that consider creating ventures with Russian partners.

About 1,100 scientists from the former Soviet Union have been or are currently working on Lawrence Livermore IPP projects in the areas of materials science and manufacturing, optics and lasers, environmental remediation, biotechnology, computation, instrumentation, petroleum geology, and software development. Many individuals at research institutes make use of telecommunications capability installed through Livermore contracts to communicate with their U.S. colleagues and the outside world.

Saito cites a promising candidate for full-scale commercialization that involves aluminum–lithium alloys and thin-walled superplastic forming, a manufacturing technique used extensively by the Russian military. Livermore materials experts are working with Boeing to evaluate the technology's commercial potential for several components of interest to their commercial aircraft and launch vehicle business. Livermore experts are also working with industry to evaluate the cost-effectiveness of automotive wheels formed in a single hydroprocessing operation from ultrahigh-strength aluminum alloys.

Don Lesuer, a Livermore engineer, is helping to commercialize these

Russian manufacturing techniques. He says, "The Russians are sharp technical people and their processes offer a lot to Western companies." He notes, however, that collaborations with U.S. industry must overcome a weak Russian business infrastructure and export controls that make shipping materials in and out of Russia difficult.

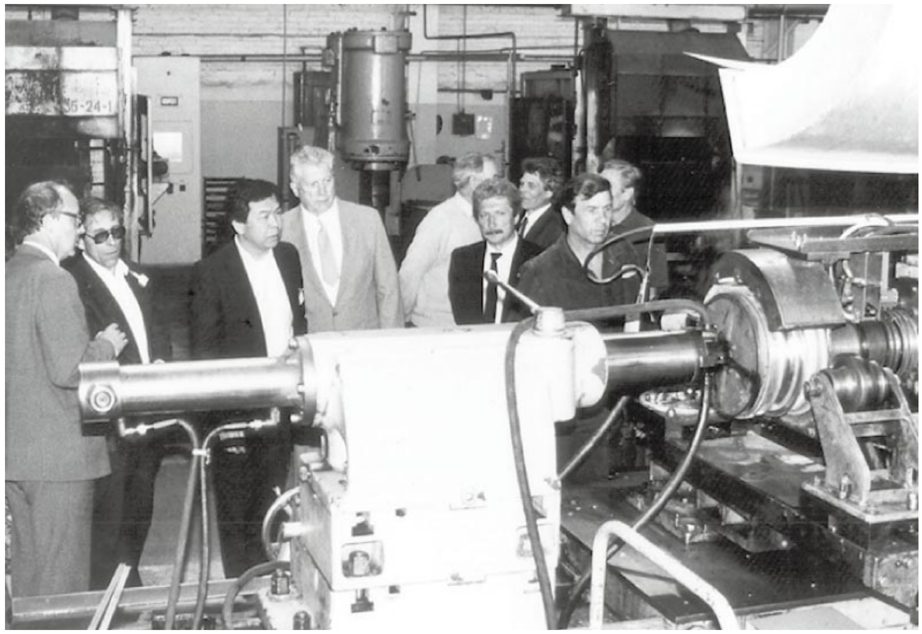
Nuclear Cities Focus

Whereas the IPP focuses on commercial developments with institutes in several countries of the former Soviet Union, the Nuclear Cities Initiative (NCI), formed in 1999, is helping former weapons experts in Russia's 10 closed nuclear cities make the transition to civilian employment. The closed cities (where Soviet nuclear weapons were designed and manufactured) were completely supported by the old Soviet system. Because of economic hardship throughout Russia, these cities currently receive little government support. What's more, their nuclear institutes are being downsized by Minatom.

The program's initial focus is on three cities: Sarov, Snezhinsk, and Zheleznogorsk. Livermore is concentrating much of its efforts at Snezhinsk, home to Russia's second nuclear weapons design laboratory and sister city to Livermore, California.

Livermore experts are working to create jobs by helping to form new businesses or enhance existing industries, including medical technologies and optical-fiber production. "The goal is to develop business approaches that have a reasonable chance of success with a modest NCI investment," says Livermore NCI leader Paul Herman.

A parallel goal is to create businesses that meet the needs of the global marketplace. Success requires the active participation of foreign industrial partners, for whom Livermore provides an important link to Russians cut off from current trade practices in democratic countries.



Livermore engineers Don Lesuer and T. G. Nieh (second and third from left) are shown with Russian colleagues as they inspect machines used for superplastic forming of automobile wheels. The process could find considerable use in the West.

Kevin Blackwell, a Livermore engineer (left), and Vladimir Zadorozhny, a communications specialist at All-Russian Institute of Technical Physics in Snezhinsk, Russia. Livermore specialists are helping to develop an open computer center at Snezhinsk to provide ready access to customers inside and outside Russia.

The well-publicized contract to begin production of kidney dialysis equipment is only one of several success stories as the program gains momentum. Livermore also signed two NCI contracts in Moscow last March. The first is for developing explosive charges for oil well casings to allow oil to flow effectively at selected depths. The second is for manufacturing a type of multiple mode optical fiber that is used in local area networks.

Livermore and the All-Russian Research Institute of Technical Physics have also agreed to form an open computer center at Snezhinsk for commercial software contracts for Western companies.

Building on the sister-city relationship, teams of Laboratory scientists and potential private-sector partners have visited Snezhinsk to explore new health-care business proposals. Possible areas of research include remote electrocardiograms, x-ray tomography, laser surgery, ultrasound for kidney stones and prostate treatment, ultraviolet blood treatment, and neutron cancer therapy.

California Representative Ellen Tauscher visited Snezhinsk in August 1999 to explore ways in which Laboratory and business leaders in the greater San Francisco Bay Area could help Russia's closed cities create sustainable jobs. "People here in Russia acknowledge that the way for Russia to emerge as an economic force is to build on the shoulders of these very talented and experienced scientists," she says.

The Right Thing to Do

By engaging thousands of former Soviet weapon scientists and enhancing the security at dozens of nuclear materials facilities, Livermore programs have made important progress in helping to prevent nuclear proliferation. Dunlop says that much of that progress has been built upon strong professional relationships with colleagues in the former Soviet Union. In nurturing increasing and effective dialogue with scientists and government officials, Livermore people are also helping to develop the more open atmosphere that is the hallmark of a democratic society.

The Russian Programs Assessment Committee, headed by former Air Force Secretary Thomas Reed, was given the task of reviewing the effectiveness of Livermore's Russian programs. "The Russian programs at Lawrence Livermore National Laboratory are the right things to do," the committee reported in its May 2000 report. "The possibility of nuclear weapons, materials, and expertise leaking out of Russian government control is one of the most horrifying threats facing mankind today. In working to contain that threat, Lawrence Livermore National Laboratory is earning the respect of the national security community."

The committee concludes that "these programs are beginning to have an impact in Russia. Materials have been secured, nuclear experts are turning to peaceful work, and transparency is coming slowly into once-dark corners of the Soviet nuclear empire. More importantly, however, these programs have created a foundation of trust between the U.S. weapons laboratories and their Russian counterparts that can help address both nations' vital national security concerns in the future."

—Arnie Heller

Key Words: All-Russian Research Institute of Technical Physics; Avangard Foundation; Comprehensive Test Ban Treaty (CTBT); highly enriched uranium; Initiatives for Proliferation Prevention (IPP); Mayak, Minatom; mixed oxide (MOX) fuel; Nuclear Cities Initiative (NCI); Material Protection, Control, and Accounting program; Proliferation Prevention and Arms Control program; plutonium; Sarov; Snezhinsk; Strategic Arms Reduction Treaty (START); warhead dismantlement.

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About the Scientist

WILLIAM DUNLOP received his B.A. from the University of Pennsylvania in 1967 and his M.S. and Ph.D in physics from the University of California at Los Angeles in 1968 and 1971, respectively. He joined Lawrence Livermore in 1972 as a physicist in the Special Projects program. From 1976 to 1985, he served as project manager and, later, program manager of various missile and weapons projects. Then for five years, he was a division leader overseeing work on thermonuclear weapons development.

Dunlop became interested in arms control work in 1979 when he was part of the U.S. delegation to the Conference on Disarmament in Geneva. In 1988 and 1989, he was a member of the U.S. delegation to the nuclear testing talks in Geneva. And from 1994 through 1995, Dunlop served as technical advisor to the U.S. Ambassador to the Geneva Conference on Disarmament, during which the Comprehensive Test Ban Treaty was negotiated. In 1990, he became leader of Livermore's Arms Control and Treaty Verification program (recently renamed the Proliferation Prevention and Arms Control program).